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BACTERIAL PURIFICATION RATES IN POLLUTED WATER¹

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Studies of the phenomena of natural purification in polluted streams have been pursued by the United States Public Health Service systematically and almost continuously since 1912. Beginning with the well-known fact that the general trend in polluted streams is toward purification, as evidenced by a decrease in bacterial count and various chemical changes, the purpose in view has been to determine more exactly the rates at which these changes take place in nature, to relate observed variations in the rates to determinate changes in such variables as temperature, the channel characteristics which determine velocity and turbulence of stream-flow, the abundance and character of the plankton, and similar conditions, in the hope of arriving eventually at a better understanding of the physical, chemical, and biological factors involved. The indices of pollution which have been found most useful for the measurement of natural purification are bacterial counts, qualitative and quantitative plankton counts, and determination of biological oxygen demand. These are closely interrelated; but in this discussion attention will be confined to changes in numbers of bacteria as indicated by plate counts on standard gelatine and agar media and quantitative fermentation-tube tests for organisms of the *coli-aerogenes* group.

The first stage of this study was an empirical determination of the extent of purification, as measured by the decrease in bacteria or oxygen demand, actually observed between two cross sections of a stream between which the times of flow corresponding to each river stage were known, choosing stretches within which no significant inflow of water or polluting matter occurred. River stretches especially suitable for such study are the Ohio River from Cincinnati to Louisville, the Illinois River from Lockport, Ill., where it receives the discharge of the Chicago Drainage Canal, to Peoria, Ill., and the

¹ From the Office of Stream Pollution Investigations, U. S. Public Health Service, Cincinnati, Ohio.

Lower Illinois River, from Peoria to Kampsville. In each of these river stretches the fresh sewage-pollution in the upper zone is heavy, and the distance to the lower end is over 100 miles, with times of flow ranging from 40 to over 300 hours. Extended observations of this nature have been made, covering widely different seasonal and weather conditions on the Ohio River during the years 1913-16 (1) and 1929-30 (2), on the Illinois River (3) in 1921-22, and on the upper Mississippi River (4). The results of these observations have been reported in detail in the publications referred to.

GENERAL OBSERVATIONS ON BACTERIAL PURIFICATION IN NATURAL STREAMS

The principal conclusions that may be drawn from these observations concerning the improvement in the bacterial content of the polluted water flowing in natural streams are as follows:

1. The general tendency is toward decrease in numbers of all bacteria which grow on the usual culture media, in all long river stretches free from added pollution. To this general statement there are, however, certain important exceptions, which are discussed hereafter.

2. The rate of decrease varies widely in different streams, in different stretches of the same stream, and even in the same stretch of stream at different times. The rates of decrease of the groups of bacteria represented respectively by the 20° gelatine count, the 37° agar count, and the *coli-aerogenes* group are not widely different.

3. So far as may be judged from decrease in turbidity due to suspended inorganic matter, sedimentation appears to be a minor factor in bringing about the observed bacterial decrease; and no evidence has been found indicating a measurable effect due to the direct action of sunlight.²

4. In any long stream stretch the *rate* of bacterial decrease is not constant but tends to diminish progressively as the pollution decreases in intensity. This condition is clearly illustrated by the data presented in table 1, plotted in figures 1 and 2, showing the bacteria remaining (in percent of the maximum) at successive sampling points in stretches of the Ohio and Illinois Rivers. The flattening of the curves in passing from the upper to the lower stations suggests that a residual bacterial content is eventually approached beyond which a further material decrease does not occur.

² The indirect effect of sunlight, exerted through its relation to the metabolism of chlorophyll-bearing plankton, may be very considerable.

TABLE 1.—*Coordinates of curves describing decrease in agar counts in relation to time of flow from zone of maximum pollution*

Time of flow from maximum zone in hours	Percentage of bacteria remaining					
	Summer season			Winter season		
	Ohio River ¹ (maximum per cc, 99,300)	Upper Illinois ² (maximum per cc, 3,420,000)	Lower Illinois ³ (maximum per cc, 254,000)	Ohio River ⁴ (maximum per cc, 3,500)	Upper Illinois ² (maximum per cc, 142,000)	Lower Illinois ³ (maximum per cc, 9,440)
0.....	100	100	100	100	100	100
5.....		48.0	65.5		54.5	76.0
10.....	67.26	29.5	47.5	80	36.3	61.8
20.....	45.37	15.8	28.6	67	20.7	45.9
30.....	30.71	9.80	19.8	56	14.0	38.0
40.....	20.90	6.50	14.7	48	10.6	34.3
50.....	14.31	4.50	11.0	42	8.45	32.6
60.....	9.88	3.21	8.50	37	7.00	31.4
70.....	6.89	2.30	6.68	33	5.90	31.0
80.....	4.88	1.70	5.28	30	5.03	31.0
90.....	3.50	1.29	4.19	27.5	4.35	31.0
100.....	2.57	.99	3.34	25.3	3.78	-----
125.....	1.30	.61	1.90	21.3	2.62	-----
150.....	.78	.26	-----	-----	1.82	-----
175.....	.50	.14	-----	-----	1.27	-----
200.....	.36	.07	-----	-----	-----	-----

¹ From Table 125, Pub. Health Bull. No. 143.² From Table 70, Pub. Health Bull. No. 171.³ From Table 74, Pub. Health Bull. No. 171.⁴ From Table 128, Pub. Health Bull. No. 143.

5. In general, the rate of bacterial decrease in a given river stretch is lower in winter, when water temperatures are, say, under 10° C., than it is in spring, summer, or autumn. Differences between summer and winter rates are illustrated by comparison of the curves in figure 1 and figure 2, showing the summer and winter decreases, respectively, for the same stretches of the Ohio and Illinois Rivers. Between 10° C. and 30° C. there appears to be no very definite correlation between rates of bacterial decrease and temperature change, other factors perhaps clouding such slight relations as may exist.

6. The initial rate of bacterial purification has been found to be higher in river stretches where pollution is most intense. This is clearly shown by the accompanying summary of data from table 1. As the time from the source of maximum pollution increases, this difference in rate is less noticeable, however, and may entirely disappear.

	Summer season		Winter season	
	Concentration per cc	Percent remaining after 10 hours	Concentration per cc	Percent remaining after 10 hours
Upper Illinois.....	3,420,000	29.5	142,000	36.3
Lower Illinois.....	254,000	47.5	9,440	61.3
Ohio River.....	99,300	67.3	3,500	80.0

7. Observed exceptions to the general tendency of bacteria to decrease in flowing streams are noted as follows:

(a) In a *fresh* mixture of sewage and water the bacterial count (including the *coli-aerogenes* index) tends definitely to *increase* for a period varying from 8 to 24 hours, the stage of increase being quite regularly longer in winter than in summer. The increase is not very great, the maximum count being usually less than 200 percent of the

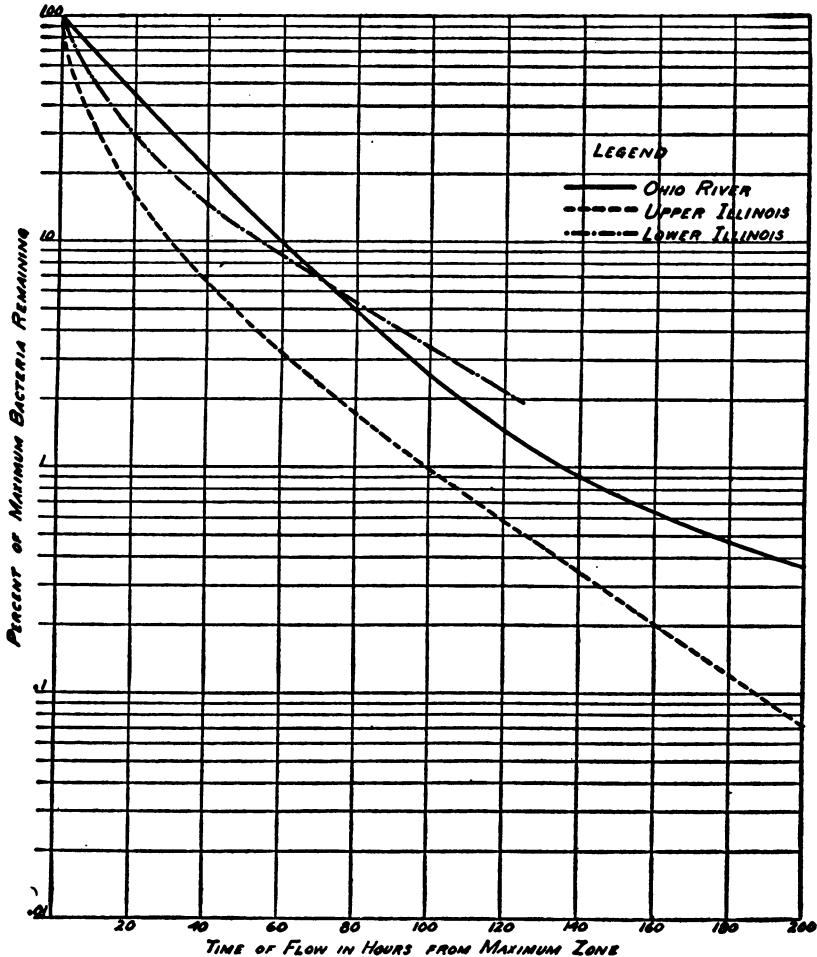


FIGURE 1.—Curves showing rates of decrease in bacteria in the Ohio and Illinois Rivers. Summer season. Agar counts 37° C., 24 hours.

initial; but within this range the tendency toward increase rather than decrease is quite constant. This observation, first made in the Ohio River immediately below the sewer outlets of Cincinnati, was so utterly unexpected that it was at first attributed to a systematic sampling error resulting from imperfect admixtures at the upper sampling stations. More extended observations in this stretch and

elsewhere have demonstrated, however, that the increase is not explained by observational error. It may, perhaps, be due to the breaking up of clumps of bacteria, which would increase the bacterial count without actual increase in numbers of bacteria; but we are inclined to believe that it is brought about by actual multiplication of the bacteria present. Figure 3 shows, for the stretch of the Ohio River immediately below the sewer outfall of Cincinnati, the primary stage of initial increase as observed in winter and summer, respectively.

(b) A similar bacterial increase is sometimes observed when two streams of quite different pollutional density are merged, a phenomenon which has been discussed in a previous publication (5).

(c) Although the over-all general trend following this initial increase is toward a progressive general decrease in bacterial numbers, a

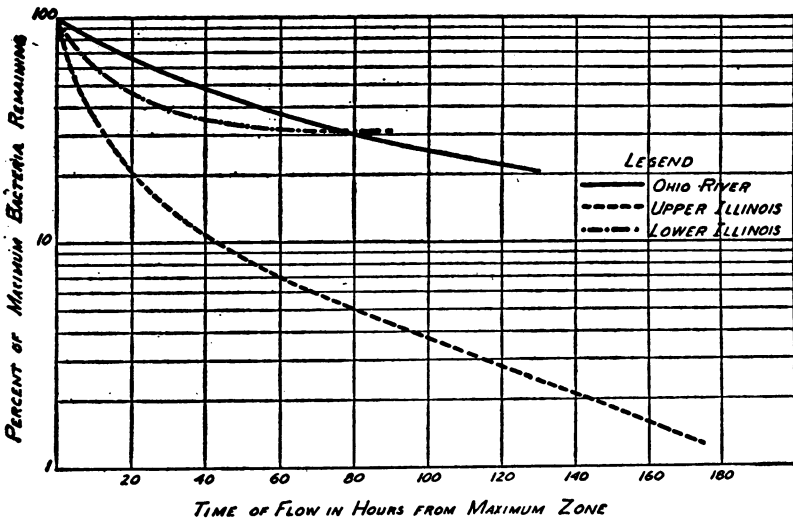


FIGURE 2.—Curves showing rates of decrease in bacteria in the Ohio and Illinois Rivers. Winter season. Agar counts 37° C., 24 hours.

more detailed examination of results reveals that frequently this trend is interrupted at intervals, and for short periods it may even be reversed. Such irregularities as occur are not constant as to location or extent, the deflections in the curves moving up or down stream from time to time without apparent cause. Figure 4 (reproduced from Public Health Bulletin No. 171), showing the actual observed numbers of bacteria at successive stations in the upper Illinois River during summer months, illustrates this point.

THE SIMULATION OF NATURAL STREAM PURIFICATION UNDER LABORATORY CONDITIONS

When observations on the Ohio River had shown the direction and extent of the bacterial purification taking place naturally in the

stream, attention was turned to reproducing these changes under controlled experimental conditions. The first stage in this study comprised a long series of observations on samples of polluted water from sampling stations in the Ohio River and other sources, the samples being stored in a variety of containers under varying conditions of temperature, light, agitation, and aeration. In one series of such experiments, in order to reproduce exactly the conditions of temperature and light obtaining in the river, containers were suspended in the stream itself. The results of these studies of stored samples, which have been reported in detail by Butterfield (6), show:

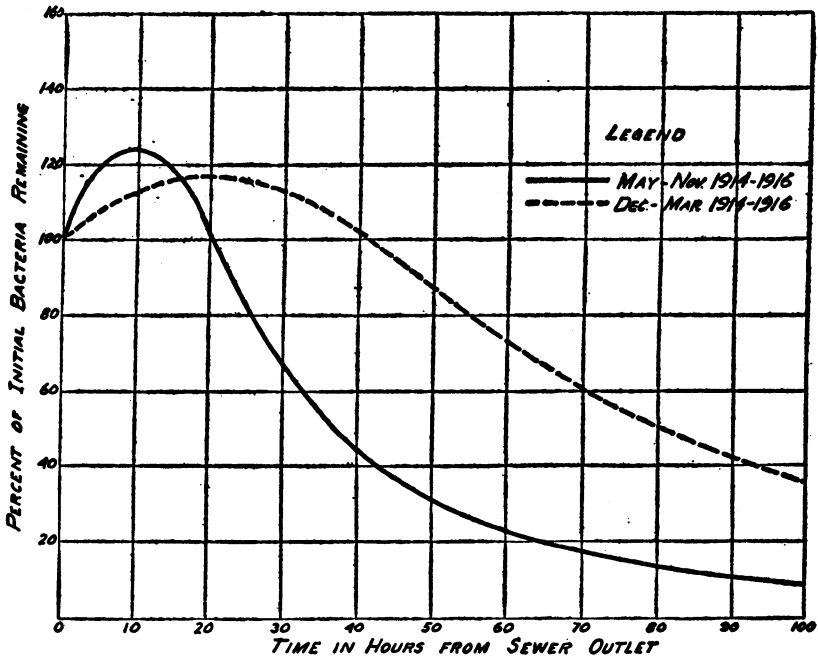


FIGURE 3.—Curves showing changes in bacterial density below sewer outlets of Cincinnati, Station 475, Ohio River. Agar counts at 37° C., 24 hours.

(a) In stored samples the first change was invariably a multiplication of the bacteria amounting to fourfold, twentyfold, or even fiftyfold, depending on the source and the temperature of storage. This increase, occurring regularly in samples collected from zones of the river in which the bacteria were rapidly diminishing, afforded definite evidence that in such zones the river water contained a food supply sufficient to support a much higher bacterial population than was actually present in the stream. It served also to demonstrate that the decrease observed in the stream could not be attributed to toxic chemical action.

(b) Following this initial increase in bacterial numbers to a well-defined maximum, the time to reach which was extended with lower

temperature of storage, there occurred an orderly progressive decrease, as in nature, resulting eventually in a number well below that of the initial sample. The rate of decrease was uniformly much lower than that observed in the river. However, in a recent critical analysis of these data, Streeter (7) has shown that, when allowance is made for the influence of sedimentation in the river, the rates of decrease in stored samples approach those observed in the river.

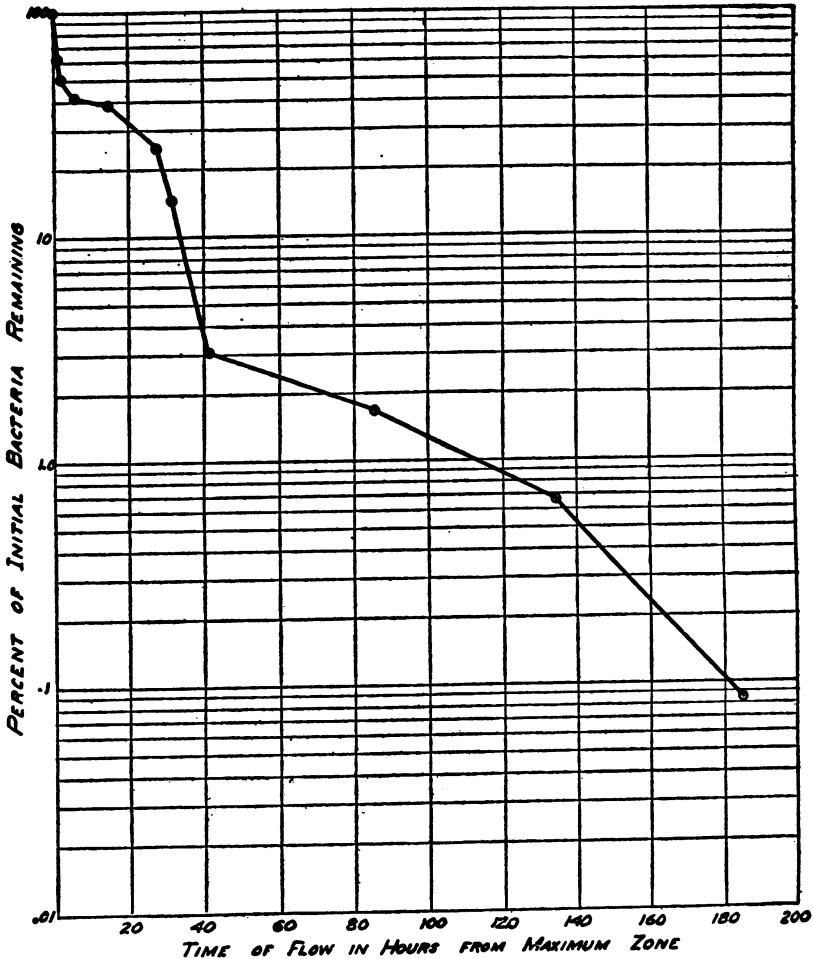


FIGURE 4.—Variation in rates of bacterial change actually observed from Station to Station in the upper Illinois River. Summer season. Agar counts 37° C., 24 hours.

RELATIONSHIP OF PLANKTON TO BACTERIA IN POLLUTED WATERS

In a study of the relation of plankton to the bacterial changes commonly observed in polluted waters, Purdy and Butterfield (8) carried out a series of experiments in which sterilized sewage was inoculated (a) with mixed cultures of sewage bacteria, no living

plankton being present; (b) with the same bacterial inoculum plus a culture of *paramoecium* or *colpidium*; and (c) with a small amount of unsterilized sewage, supplying the bacteria and protozoa found in nature. Their studies, extended later by Butterfield, Purdy, and Theriault (9), show:

(1) When no living protozoa are present, the bacteria multiply rapidly to a maximum, which is maintained at nearly the same level for several weeks or declines *very* slowly.

(2) When living protozoa are present, the bacteria increase at first to nearly the same maximum, then decrease rapidly to a much lower level, following a course similar to that observed in stored samples of unsterilized sewage or polluted river water.

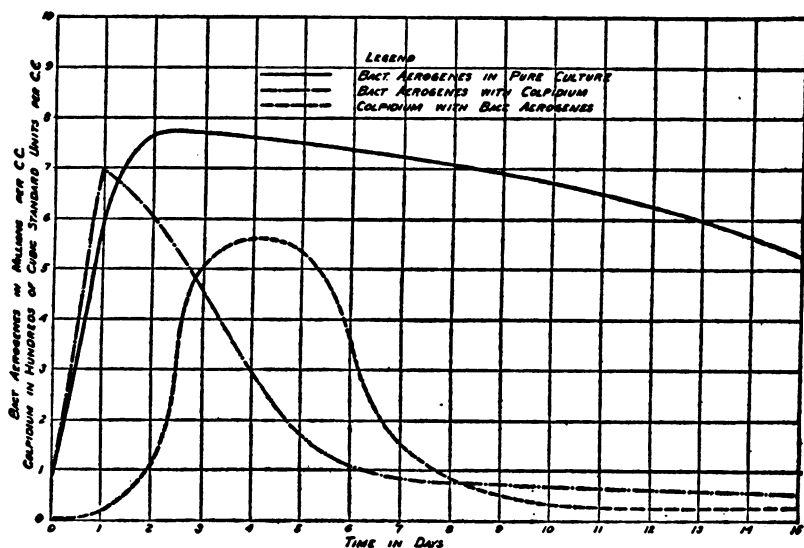


FIGURE 5.—Bacteria and Colpidium counts in dilute dextrose peptone solution, incubated at 20° C., when inoculated with (1) *Bact. aerogenes* in pure culture and (2) *Bact. aerogenes* and Colpidium growing together each in pure culture. Average of 10 experiments.

(3) During the stage of rapid increase of bacteria, the protozoa likewise multiply rapidly to a maximum, which is reached after the bacterial maximum, and then decline at about the same rate as the bacteria.

(4) In long-continued experiments it happens not infrequently that after the decrease in protozoa has set in, the bacterial count shows a secondary increase, followed in turn by a subsequent decline.

Figure 5 (reproduced from Butterfield, Purdy, and Theriault (9)) illustrates the characteristic difference of bacterial history in the presence and in the absence of protozoa.

It thus seems well established that the rapid decrease in bacteria characteristically observed in polluted waters is due primarily not to

lack of adequate food supply, the action of toxic substances, removal by sedimentation, or injury by sunlight, but to destruction by predatory plankton, which are dependent upon living bacteria for their food supply. There is, indeed, much evidence that even in the presence of predatory plankton the sewage bacteria in polluted waters are continuously multiplying at a quite rapid rate, and that their observed rate of decrease is actually the net difference between birth rate and death rate, foraging plankton being chiefly responsible for the latter.

From this viewpoint, any disturbance of the existing balance between plankton and bacteria would influence the rate of bacterial change (either decrease or multiplication) in polluted water. Thus the reversal in direction of change observed regularly in stored samples as compared with natural streams may be regarded as the reflection of some such disturbance of the biological balance in the stored sample, a disturbance which limits the activities of the plankton rather than of the bacteria. In the same way, the mixture of two streams of widely different degrees of pollution would create a sudden change in environmental conditions to which the plankton would require some time to become accustomed, the bacteria in the meantime continuing to multiply.

ARTIFICIAL CHANNEL EXPERIMENTS

In an effort to provide an experimental set-up in which a biological balance could be maintained more nearly comparable with that existing in natural streams, a system of artificial water channels was constructed on the station grounds in 1926 and has been operated at intervals since that time.

As originally constructed, the channels consisted of a series of 48 galvanized iron troughs, each 90 feet long, 2 inches wide, and 6 inches deep, the interior well covered with carbon paint to avoid contact of the water with metal, arranged in tiers and at an adjustable gradient that would permit gravity flow throughout the system at various desired velocities. Connections between successive troughs were made by short sections of rubber hose 1 inch in diameter, the outlet ends of which were adjustable in elevation to control the depth of flow. Each tier of troughs was covered with a narrow roof, but the sides were exposed to admit light. Later the entire system was housed under a glass cover to eliminate interruptions in operation caused by freezing temperatures, heat sufficient for this purpose being provided by gas-burning units.

The water passed through the channels was delivered from the Ohio River by a pump installed originally to serve an experimental filtration plant. The volumes delivered to the channels were regulated

by the use of fixed, calibrated orifices under constant head. For studying the rates of purification of the water flowing in the channels, the average velocity of flow through the system under varying conditions was determined. Sampling stations for the experimental work were then located at successive points along the troughs corresponding to fixed periods of time of flow from the inlet.

EXPERIMENTS WITH RAW OHIO RIVER WATER

In the first group of experiments, raw Ohio River water passed through the channel system continuously during week days but stood motionless in the various troughs over the week-ends. For some of these test runs, water was added at the rate of 0.5 gallon per minute, giving a velocity of 1.09 feet per minute, corresponding to a total time of passage through the system of 66 hours. For other tests, the rate of flow was increased to a velocity of 1.56 feet per minute, equivalent to a total time of passage of 46 hours. This was found to be a more suitable rate and was maintained in later experiments.

The 14 experiments comprising the first series may be combined into 3 groups, in which the experimental conditions were as follows:

Series	Date, 1926-27	Rate of flow, feet per minute	Observed temperature of water, °C.		
			Maximum	Minimum	Average
1 to 8.....	August 16 to October 9.....	1.09	26.6	8.8	20.6
9 to 11.....	October 18 to November 6.....	1.56	16.7	1.9	8.1
12 to 14.....	November 8 to May 27.....	1.56	21.3	.8	12.0

The average initial bacterial count (on agar at 37° C. or 20° C., 24 hours) in each group of experiments is shown in table 2. The counts varied, of course, from day to day, but not excessively, 75 percent or more of the samples collected at the inlet of the channels showing between 5,000 and 20,000 bacteria per cubic centimeter.

The average course of bacterial change for each of these three groups of experiments is presented in table 2 in the form of percentages of the initial numbers of bacteria remaining after successive times of flow.

These results disclose a generally consistent reduction in bacteria as the water passed through the channel system, and particularly an absence of the initial rise in contrast with that always obtained in the stored samples. The reduction in bacterial numbers was somewhat more rapid in the later series, after the velocity of flow had been increased and after heavier biological growths had developed on the channel-wetted surfaces. Although these observed rates of decrease are by no means uniform, but on the contrary are inter-

mittent, nevertheless the ultimate tendency is toward a gradual reduction in bacterial numbers. If smooth curves are drawn, by observation, through the plotted points, a rough comparison is afforded between the average purification rates observed in these experiments and those observed in the Ohio River. The curves for this comparison are shown in figure 6.

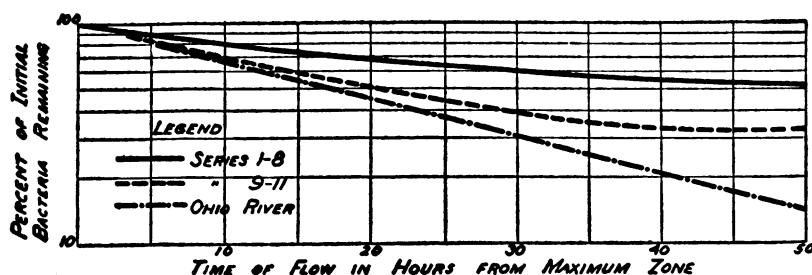


FIGURE 6.—Comparison of rates of bacterial change in Ohio River water flowing in the experimental channels with those observed in the river itself below Cincinnati. Summer season. Agar counts 37° C., 24 hours.

TABLE 2.—Raw Ohio River water—Percentage of initial bacteria remaining after stated times of flow through channels

Flow time, hours	Series 1 to 8 0.5 gallon per minute	Series 9 to 11 0.75 gallon per minute	Series 12 to 14 0.75 gallon per minute	Flow time, hours	Series 1 to 8 0.5 gallon per minute	Series 9 to 11 0.75 gallon per minute	Series 12 to 14 0.75 gallon per minute
	37° C. agar plate counts. Influent content = 13,800 per cc = 100 percent	37° C. agar plate counts. Influent content = 9,920 per cc = 100 percent	20° C. agar counts. Influent content = 13,500 per cc = 100 per- cent		37° C. agar plate counts. Influent content = 13,800 per cc = 100 percent	37° C. agar plate counts. Influent content = 9,920 per cc = 100 percent	20° C. agar counts. Influent content = 13,500 per cc = 100 percent
0.....	100	100	100	26.....	63.3	48.6	37.6
2.....	97.0	96.0	83.0	28.....	66.8	43.0	41.9
4.....	86.2	93.1	76.2	30.....	64.9	32.1	39.7
6.....	96.4	90.2	78.5	42.....	49.8	-----	41.0
10.....	-----	-----	72.7	44.....	58.7	34.5	55.0
12.....	-----	-----	58.9	46.....	53.0	34.0	48.3
14.....	-----	-----	60.4	48.....	51.5	-----	-----
18.....	73.9	53.7	58.2	50.....	48.0	-----	-----
20.....	70.7	51.3	49.0	52.....	50.0	-----	-----
22.....	63.1	50.7	53.4	54.....	44.2	-----	-----
24.....	65.0	45.8	47.3	56.....	43.5	-----	-----

Although the rates of purification in the channels are much lower than those of the Ohio River below Cincinnati, as shown on the plot, it is to be noted that the channel water was much less polluted than the river below Cincinnati. However, in the stretch of Ohio River from Portsmouth, Ohio, to above Cincinnati, where at the upper station the bacterial density was 1,450 per cc (during the summer of 1914), a decrease of 46 percent took place in a time of flow period averaging 67.9 hours—a considerably slower rate of decrease than that occurring in the channels.

EXPERIMENTS WITH MIXTURES OF SEWAGE AND OHIO RIVER WATER

A further series of experiments was next undertaken in which graded changes were made in the initial concentration of bacteria in the influent channel water, in order to simulate more closely the pollution range of the Ohio River below Cincinnati, as well as to check the relation between purification rate and bacterial density. These higher bacterial densities in the channel water were obtained by mixing with the Ohio River water varying amounts of domestic sewage previously stored for 12 hours or more in a storage tank, in order to remove gross suspended matter and to obtain a more stable mixture. Operating data of this series of experiments are given in table 3.

The results of these experiments, presented in table 4, indicate that the rates of purification are by no means uniform or regular from beginning to end of the flowing-through period. They are consistent to the extent that all show a decline in numbers of bacteria; and although apparent increases occur at times, in no case does the increase exceed the initial density. Generally the most rapid decrease was observed in the first few hours, with secondary increases thereafter. Furthermore, there appears to be no orderly relation between rates of decrease and initial bacterial concentration within the fairly narrow range of variation represented. There was, however, a quite definite tendency for higher purification in the later of the series of experiments which may be ascribed in part at least to the building up of a more active biological "carpet" in the channels as the season advanced. In general the tendency was for a fairly rapid decline to a minimum, followed thereafter by oscillations up and down around this level. These oscillations were irregular from day to day in that the zone of decline one day, for example, might have changed to a zone of increase the next. The oscillations probably represent the continuous effort of the plankton and bacteria to reach an eventual stable balance. It seems fair to conclude that, under the conditions of these experiments at least, the bacterial reduction is not a continuous and regular process, but is the resultant of more or less periodic fluctuations around a trend generally tending to lower numbers of those species which grow on ordinary culture media.

TABLE 3.—*Characteristics of series of experiments with mixtures of sewage and Ohio River water*
 [Velocity of flow 1.56 feet per minute]

Experiment no.	Date, 1927	Number of days	Percent sewage concentration	Temperature, ° C.						Bacteria per cc. agar, 37° C., 24 hours		Maximum bacterial reduction	
				Of water			Of air						
				Average	Maxi- mum	Mini- mum	Average	Maxi- mum	Mini- mum	Initial	Mini- mum	Percent	Hour reached
15-----	May 31 to July 23-----	53	5	20.8	29.0	12.0	20.6	35.6	11.1	111,000	35,300	31.8	46
16-----	August 1 to August 13-----	13	15	21.0	27.5	15.5	17.8	32.2	12.2	150,000	33,600	22.4	4
17-----	August 14 to August 26-----	14	30	22.2	25.0	14.0	16.1	28.9	8.9	550,000	149,000	27.1	14
18-----	August 28 to September 9-----	13	45	25.4	28.0	17.0	18.3	32.2	12.2	1,490,000	442,000	29.7	16
19-----	September 10 to September 24-----	14	30	20.4	23.6	8.0	16.7	25.6	4.4	876,000	91,200	10.4	38
20-----	September 25 to October 8-----	14	15	19.9	25.0	12.0	16.7	30.0	6.7	136,000	20,300	14.9	14
21-----	October 9 to October 22-----	14	5	12.6	21.5	4.0	8.3	25.6	2.2	72,000	6,740	9.4	18
22-----	October 31 to November 5-----	6	5	12.0	21.5	4.0	7.8	26.7	2.2	105,000	5,000	4.8	20

TABLE 4.—*Mixtures of Ohio River water and sewage—Agar counts, 37° C., after 24 hours' incubation*

Exp. no. and percent sewage.....	Experiment 15, 5 per- cent sewage	Experiment 16, 15 per- cent sewage	Experiment 17, 30 per- cent sewage	Experiment 18, 45 per- cent sewage	Experiment 19, 30 per- cent sewage	Experiment 20, 15 per- cent sewage	Experiment 21, 5 per- cent sewage	Experiment 22, 5 per- cent sewage
Initial count.....	111, 000	150, 000	550, 000	1, 490, 000	876, 000	136, 000	72, 000	105, 000
Flow time, hours	Percentage of initial bacteria remaining after stated times of flow through the channels							
0.....	100	100	100	100	100	100	100	100
2.....	90.0	31.4	77.6	55.7	54.6	57.8	55.3	43.0
4.....	79.5	22.4	44.7	60.9	30.2	45.0	18.8	16.8
6.....	76.2	31.7	41.0	52.7	37.5	30.3	25.7	9.0
8.....		38.1	38.3	64.2	27.4	26.7	20.8	8.3
10.....		49.5	49.7	52.6	39.8	33.2	14.3	7.6
14.....		40.2	27.1	31.0	37.5	14.9	10.3	6.9
16.....		56.0	29.8	29.7	26.7	23.8	11.1	5.9
18.....	62.5	33.5	38.5	37.1	29.8	26.4	9.4	7.6
20.....	54.9	39.2	53.2	36.4	19.1	24.1	13.9	6.3
22.....	55.7	47.1	45.5	36.2	36.8	26.6	10.8	6.4
24.....	48.9	48.0	47.4	39.8	27.1	34.1	9.8	15.4
26.....	50.5	44.1	55.4	52.1	29.9	35.9	10.2	8.6
30.....	34.1	36.1	42.7	46.6	31.8	35.6	12.6	4.8
34.....		34.4	82.0	75.2	37.8	43.5	9.7	6.1
38.....		27.4	84.0	51.3	10.4	33.3	9.8	9.6
42.....	39.4	27.3	93.5	56.1	31.9	37.4	13.5	11.3
46.....	31.8	33.8	71.0	60.0	30.5	31.8	10.6	7.6

EXPERIMENTS WITH PHYSICAL CHANGES IN CHANNELS

The final series of experiments to be discussed here was designed to provide environmental conditions favorable to a more abundant development of plankton and to observe the effect of such increased plankton growth on the rates of bacterial decrease. For this purpose the uniform cross section of the channel system was changed by inserting at intervals some lengths of wider bottom area and some of steeper gradients. The most important alteration, and the only one which appeared to effect the result, was the replacement of the first 90-foot length of 2-inch channel by a section 12 inches wide and having a fall of 1.5 feet in that distance. The bottom of this section was covered with gravel in order to increase the wetted surface and to make the flow more turbulent. The net effect of this change was to reduce the time of flow through this first 90-foot channel from 1 hour to approximately 20 minutes, and to provide a greatly increased wetted area with more turbulence and aeration, resembling the conditions commonly met in shallow brooks.

In order to provide more adequately for adjustment of the biological life to the conditions under which each experiment was conducted, especially to the change in sewage strength in the influent mixture, *each test was continued without interruption for not less than 4 weeks*, all controllable factors meanwhile being maintained as nearly uniform as possible. A total of six experiments comprise this group, of which the general features of operation and the results obtained are presented in tables 5 and 6, respectively.

TABLE 5.—*Characteristics of series of experiments with mixtures of sewage and Ohio River water flowing through gravel-lined channel bottom*

Experiment no.	Date, 1928	Num- ber of days	Percent sewage concen- tration	Temperature, ° C.				Bacteria, per cc agar, 37° C., 24 hours		Maximum bac- terial reduction		Ratio; Agar count B. coli Index	
				Of water		Of air		Initial	Mini- mum	Per- cent reached	Hour reached	Initial	Final, 48 hours
				Aver- age	Maxi- mum	Mini- mum	Aver- age						
23	May 28 to June 16	20	5	18.2	25.0	11.5	18.9	62,200	496	99.2	44	6.5	34.3
24	June 25 to July 21	27	15	22.2	28.0	14.0	23.3	123,000	354	99.7	22	15.1	823
25	July 23 to August 18	27	30	25.0	31.5	18.0	24.4	626,000	2,470	99.6	45	3.5	71.8
26	August 20 to September 22	34	45	22.6	31.5	13.5	23.0	707,000	3,950	99.4	45	3.5	29.9
27	September 24 to October 27	34	30	19.6	28.0	10.5	20.0	424,000	4,890	98.9	45	4.3	25.3
28	October 28 to November 24	27	15	10.9	21.0	4.5	12.5	104,000	991	96.0	42		

TABLE 6.—Ohio River water and sewage in gravel-lined channel

[illegible]

An inspection of these rates of bacterial decrease indicates *very much* higher rates of purification than were obtained in the previous experiments, and especially during the first 2 hours. In fact, the greatest reduction occurred during the 20 minutes of flow through the first channel, which, as above noted, was changed to a steep-sloping trough 12 inches wide and having a gravel-lined bottom. Luxuriant growths of numerous species of plankton developed in this channel, becoming attached both to the gravel and the channel sides, forming a spongy mass over and through which the water trickled. This biological carpet presumably effected the higher rate of bacterial decrease of the flowing stream amounting, in some of the experiments, to as much as 90 percent in the first 20 minutes. This is a much more rapid rate of purification than has been observed in any of the natural streams which have been studied; it more nearly approximates the rates observed in sewage sprinkling filters.

Following this preliminary rapid reduction in bacteria, the decline continues at a slower but nonuniform rate, fluctuating and even for short periods showing moderate increases in bacterial numbers. Again there may be noted a certain rhythm in these changes moving up and down about an average level, or a generally declining trend. Such variations are, of course, more clearly defined in the daily observations in which these wave effects are not smoothed out by the system of averaging. Again, as in previous experiments, no consistent relation is shown between the rate of purification observed and the initial bacterial content, within the limits studied, although there is a very definite tendency for the rate to decline in passing down the channel.

In general, the rates of bacterial decrease observed in this group of experiments are much more rapid in the first third hour (corresponding to the time of passage through the first wide channel) than any that have been observed in large natural streams. The most nearly comparable data available are those of the upper Illinois River where the current is swift and turbulent and where attached plankton growths are prolific. Using averages of observations made at approximately the same times of flow from points of maximum bacterial concentrations, comparative percentages of remaining bacteria obtained. These data, presented in Table 7, the 37° C. agar counts of which are plotted in figure 7, clearly illustrate this higher rate of bacterial purification in the experimental channels.

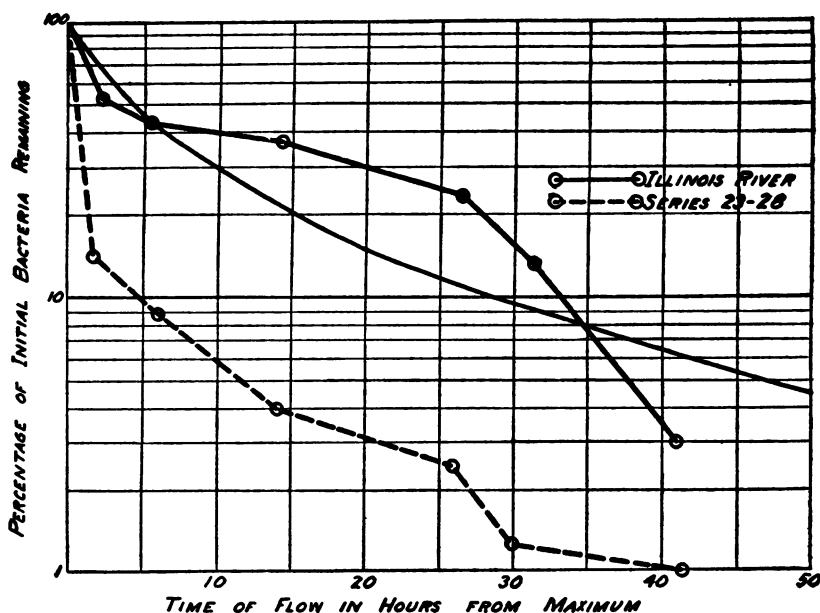


FIGURE 7.—Comparison of rates of bacterial change in mixtures of sewage and Ohio River water flowing in the experimental channels with those observed in the Illinois River. Agar counts at 37° C., 24 hours.

TABLE 7.—Comparison of rates of bacterial change (upper Illinois River and experimental channels)

Time of flow (hours)	Percentage of bacteria remaining			
	37° C. agar count		Coli-aerogenes group	
	Illinois River	Channels, average of series 23 to 28	Illinois River	Channels, average of series 24 to 28
0.0	100	100	100	100
2.0	51	14	47	8.9
5.5	42		27	
6.0		8.8		7.8
14.3	38		38	
14.0		4.0		1.1
27.0	24		20	
26.0		2.5		.5
31.8	14		16	
30.0		1.3		.7
41.1	3.0		5.6	
42.0		1.0		1.00

SUMMARY

The general conclusion to be drawn from these observations on the bacterial counts in polluted waters under natural and experimental conditions is that the reduction in bacteria which is consistently observed is due chiefly to the activity of bacteria-eating plankton, which are wholly or in part dependent upon the bacteria for their food

supply. Except for the presence of predatory plankton, the environment existing even in moderately polluted waters is sufficiently favorable to permit considerable multiplication of such bacteria as are included in standard plate counts, at rates varying with temperature. It is believed, therefore, that the decrease in bacteria which is usually observed in polluted streams is to be interpreted as the difference between their rate of multiplication and the rate of destruction by foraging plankton. Any disturbance of the existing balance between the plankton and the bacterial population alters the rate of change in the latter; and since this balance is in constant process of readjustment, the rate of bacterial decrease is constantly changing, and not infrequently the direction of change is temporarily reversed.

The most favorable conditions for rapid bacterial reduction are met where a highly polluted water, rich in plankton food supply, passes over an attached, stationary plankton "carpet". Physical factors tending to increase the rate of bacterial destruction by bringing about this biological condition are (a) increase of the wetted area in proportion to volume, and (b) turbulence in the stream, promoting contact with the biological carpet and aeration.³

Natural streams exhibit all grades of variation with respect to these conditions, ranging from deep, sluggish channels with a minimum of wetted surface area in proportion to volume, up to broad, shallow riffles such as occur in trickling brooks. It would seem reasonable to expect, therefore, a correspondingly wide variation in their natural purification rates; and, in fact, the evidence thus far accumulated indicates a continuous gradation from the low rates of purification observed in deep broad rivers to the extremely rapid rates occurring in sewage trickling filters. It is probable that the dominant physical factor in these different rates is the relationship between volume of flow and wetted area of the channel cross section.

The view that attached plankton, on the bottom and margins of the stream channel, play a large part in bacterial destruction explains the increase in bacteria which is observed when polluted river water is removed from the stream and stored in laboratory containers. Storage, in effect, temporarily eliminates all plankton-covered wetted surfaces and at the same time produces, perhaps, other minor changes in environmental conditions to which the plankton require a certain time to become adjusted.

ACKNOWLEDGEMENTS

Acknowledgement is due to the personnel of the Stream Pollution Investigations Station for performing the extensive analytical work on which the data herein presented are based, and especially to

³ Such physical and biological conditions (10) are found in the Illinois River immediately below the outlet of the Chicago Drainage Canal, and in this zone bacterial purification proceeds at a very rapid rate.

technical assistant in sanitary engineering C. T. Carnahan, who was in direct charge of operation of the channel system. To our consultant, Dr. W. H. Frost, grateful appreciation is expressed for his continued interest and helpful suggestions contributed throughout the period of this study.

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THE WEIL-FELIX REACTION IN EXPERIMENTAL ROCKY MOUNTAIN SPOTTED FEVER AND CERTAIN OTHER TYPHUS-LIKE DISEASES¹

By GORDON E. DAVIS, *Bacteriologist, United States Public Health Service*

In the experimental study of typhus-like diseases the guinea pig is the laboratory animal most extensively used. This is because of its value for the maintenance of strains of *passage* virus and the characteristic febrile reaction and lesions of spleen, brain, and scrotum which some of the viruses induce. The rabbit, however, though of less value in some respects, has a special field of usefulness, since it produces

¹ Contribution from the Rocky Mountain Laboratory of the United States Public Health Service at Hamilton, Mont.

Presented before the American Society of Tropical Medicine, San Antonio, Tex., Nov. 16, 1934.

agglutinins for the several *Proteus* X types. These have not been demonstrated in the guinea pig by the customary procedures.

As early as 1921 Weil and Felix showed that when rabbits were injected with brain suspensions of typhus-infected guinea pigs the formation of agglutinins for *Proteus* OX 19 was "remarkably constant and uniform." Maxcy (1929) and Dyer et al. (1931 a and b) obtained similar results with endemic typhus of the United States. Munter (1928) found that when rabbits were injected with Rocky Mountain spotted fever virus the Weil-Felix reaction was positive with the X 19 strain, while Kuczynski (1927) found this to be true only occasionally. In one instance the latter noted a low titer for an X 2 strain, a result of interest in view of our recent findings, to be mentioned later.

In human sera from the typhus-like diseases the *Proteus* X type agglutinins which are almost constantly present, which appear early in the disease, and which attain a high titer, are termed "main" agglutinins, while the type which appear later and in low titer or are at times altogether absent are classed as "group" agglutinins. Felix has pointed out that only the main agglutinins can be demonstrated in rabbits. He has further shown that a subsequent injection of the same *passage* virus does not restimulate the production of agglutinins, inasmuch as the quantity of virus injected is very small and does not multiply under the given conditions. However, if following the initial infection the rabbit is infected with a different typhus virus, agglutinins are again produced, the type agglutinin depending on the virus. Felix has consequently (1933) recommended the rabbit "for the analysis of the antigenic structure of the different typhus viruses by means of serological tests with the various types of *Proteus* X."

In line with Felix's suggestion and in continuation of certain former studies, several groups of rabbits were injected intraperitoneally or intravenously with guinea pig *passage* virus of one of the typhus-like diseases and later with that of another. Various combinations of the following viruses have been used: (1) Rocky Mountain spotted fever; (2) Sao Paulo exanthematic typhus; (3) endemic typhus of United States; and (4) boutonneuse fever.

All rabbits were bled previous to the injection of virus to determine the agglutinin content of the "normal" serum. They were bled again, routinely, on the fourteenth and sixteenth days following injection, as frequent trial bleedings have shown that, with the viruses used, the maximum agglutinin titers are obtained at this time. Subsequent bleedings were made at the same intervals following the second injection of virus. *Proteus* X strains OXK, OX2, HX2, and OX19 were used for the agglutination test. The serum-bacterial suspension mixtures were incubated at 37° C. for 2 hours and the

readings made following an additional 36 to 48 hours at approximately 8° C.²

EXPERIMENTAL DATA

Of six rabbits injected with the virus of exanthematic typhus of Sao Paulo and subsequently with the virus of spotted fever, 100 percent gave a positive Weil-Felix reaction with OX2, OX19, or both, following the first injection, while all were negative following the second. When the order of injection of the two viruses was reversed, the positive reaction again followed the first injection, while following the second there was no restimulation of agglutinins.

Of 10 rabbits injected with the virus of spotted fever and subsequently with virus of boutonneuse fever, 100 percent gave a positive Weil-Felix reaction with OX2, OX19, or both, following the first injection and none following the second.

Of 24 rabbits injected with boutonneuse-fever virus and subsequently with the virus of spotted fever, 100 percent were essentially negative following the first injection, while only 4 were positive following the second.

Of 6 rabbits injected with the virus of endemic typhus 5 gave a positive Weil-Felix reaction with *Proteus* OX19, but the results were negative following the subsequent injection of spotted-fever virus which produced typical thermic curves, scrotal lesions, and a positive Weil-Felix reaction in 2 control rabbits. When the viruses were injected in the reverse order, all animals gave a positive reaction with OX2 following the injection of spotted-fever virus, while only OX19 agglutinin appeared after the injection of typhus virus.

Selected examples of the above reactions are shown in tables 1 to 5. The results of agglutination tests with human sera used as controls on the agglutinability of the several *Proteus* X strains are shown in table 6.³

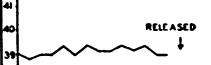
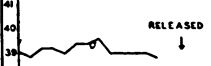
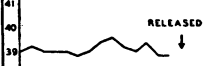

DISCUSSION

The above data show that, following the injection of either spotted fever or Sao Paulo typhus virus into rabbits, X2 agglutinins are present even more regularly than the X19 type. This is the first record of the presence of these agglutinins in significant titer in rabbit sera following infection with any of the typhus viruses. Both types of agglutinins are also present in human sera, although in the latter X19 agglutinins are usually of higher titer. These reactions afford


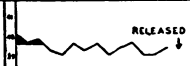
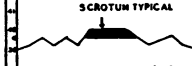


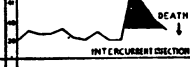
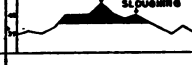
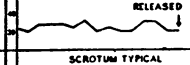


² To make certain that our *Proteus* X strains were of standard agglutinability, several sera were sent to Dr. A. Felix, of the Lister Institute, London, without comment other than that they were from spotted-fever infected rabbits. The results kindly forwarded by Dr. Felix were comparable in all respects with those recorded in this paper.

³ I take this opportunity to thank Dr. R. Lewthwaite, of the Institute of Medical Research, Kuala Lumpur, Federated Malay States, and Dr. James G. McAlpine, director of laboratories, State Board of Health, Montgomery, Ala., for sera from typhus cases, and Dr. A. Felix, of the Lister Institute, London, for *Proteus* X strains and his further kindness in testing the several sera sent him.

further evidence of the close relationship or identity of spotted fever and Sao Paulo typhus as indicated by former experimental studies which showed reciprocal cross-immunity, reciprocal cross-protection

TABLE 1.— ROCKY MOUNTAIN SPOTTED FEVER AND EXANTHEMATIC TYPHUS OF SAO PAULO IN RABBITS						
EACH RABBIT RECEIVED 1 ^{cc} . SPOTTED FEVER GUINEA-PIG PASSAGE VIRUS (BLOOD)				EACH RABBIT RECEIVED 1 ^{cc} . SAO P. TYPHUS GUINEA-PIG PASSAGE VIRUS (BLOOD)		
RABBIT NO.	PROTEUS X STRAIN	TEMPERATURE RECORD FOLLOWING INJECTION	W-E REACTION 14 TO 16 DAYS FOLLOWING INJECTION	TEMPERATURE RECORD FOLLOWING INJECTION	W-E REACTION 14 TO 16 DAYS FOLLOWING INJECTION	
5246	OX19	TEMPERATURES RANGING	32.0		4.0	
	OX2		32.0		2.0	
	HX2		32.0		2.0	
	OXK		2.0		0	
5247	OX19	FROM 40°C. TO 41°C. FOR	100		80	
	OX2		100		80	
	HX2		100		40	
	OXK		20		20	
5248	OX19	SEVERAL DAYS COMPLETE	40		40	
	OX2		100		40	
	HX2		100		20	
	OXK		20		20	
5252	OX19	RECORDS NOT KEPT	100		20	
	OX2		0.40		100	
	HX2		0.40		40	
	OXK		20		20	

0 = NEGATIVE IN FINAL SERUM DILUTION OF 1:20

TABLE 2.—EXANTHEMATIC TYPHUS OF SAO PAULO AND ROCKY MOUNTAIN SPOTTED FEVER IN RABBITS						
EACH RABBIT RECEIVED 1 ^{cc} . SAO PAULO TYPHUS GUINEA-PIG PASSAGE VIRUS (BLOOD)				EACH RABBIT RECEIVED 1 ^{cc} . SPOTTED FEVER GUINEA-PIG PASSAGE VIRUS (BLOOD)		
RABBIT NO.	PROTEUS X STRAIN	W-E REACTION BEFORE INJECTION	TEMPERATURE RECORD FOLLOWING INJECTIONS	W-E REACTION 14 TO 16 DAYS AFTER INJECTION	TEMPERATURE RECORD FOLLOWING INJECTIONS	W-E REACTION 14 TO 16 DAYS AFTER INJECTION
5220	OX19	0		0.0		0
	OX2	0		3.20		0
	HX2	0		3.20		0
	OXK	0		4.0		2.0
5221	OX19	0		0.0		0
	OX2	0		0.40		100
	HX2	20		0.40		100
	OXK	0		2.0		0
5223	OX19	40		0.0		4.0
	OX2	0.0		0.40		0.0
	HX2	0.0		12.00		0.0
	OXK	20		0.0		0
5224	OX19	0		0.0		4.0
	OX2	20		3.20		4.0
	HX2	0		3.20		0
	OXK	0		0.0		0
5238	OX19			CONTROLS		0
	OX2					3.20
	HX2					100
	OXK					0.0
5239	OX19			ONLY SPOTTED FEVER VIRUS		0.0
	OX2					3.20
	HX2					100
	OXK					4.0

or virus neutralization, and that equal protection is conferred by either spotted fever vaccine or Sao Paulo typhus vaccine against both diseases. (Parker and Davis, 1933; Davis and Parker, 1933; Dyer, 1933; Monteiro, 1933.)

While the Weil-Felix reaction with rabbit sera emphasizes the similarity of the antigenic structure of the viruses of spotted fever and Sao Paulo typhus, it also indicates a difference between these two viruses and that of boutonneuse fever in which the Weil-Felix reaction



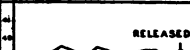
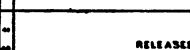
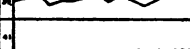


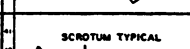
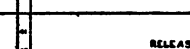
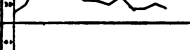
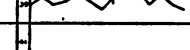

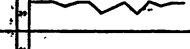
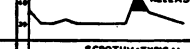

TABLE 3.—ROCKY MOUNTAIN SPOTTED FEVER AND ENDEMIC TYPHUS (U.S.A.) IN RABBITS					
EACH RABBIT RECEIVED 1 ST SPOTTED FEVER GUINEA-PIG PASSAGE VIRUS (BLOOD)				EACH RABBIT RECEIVED 3 RD ENDEMIC TYPHUS PASSAGE VIRUS (TESTICULAR WASHINGS)	
RABBIT NO.	PROTEUS X STRAIN	TEMPERATURE RECORD FOLLOWING INJECTION	W-E REACTION 14 TO 16 DAYS AFTER INJECTION	TEMPERATURE RECORD FOLLOWING INJECTION	W-E REACTION 14 TO 16 DAYS AFTER INJECTION
5253	OX19	TEMPERATURES RANGING FROM	32.0		12.00
	OX2		0.40		0.0
	HX2		32.0		4.0
	OXK		4.0		4.0
5255	OX19	40°C TO 41°C FOR SEVERAL	4.0		64.0
	OX2		32.0		0.0
	HX2		1.00		0.0
	OXK		4.0		2.0
5236	OX19	DAYS COMPLETE RECORDS NOT	0.0		120.0
	OX2		32.0		4.0
	HX2		32.0		-2.0
	OXK		4.0		0
5254	OX19	KEPT	0.0		0.0
	OX2		1.00		4.0
	HX2		1.00		4.0
	OXK		2.0		4.0
5208	OX19	CONTROL RABBIT RECEIVED ONLY ENDEMIC TYPHUS VIRUS	4.0		32.0
	OX2		4.0		0
	HX2		4.0		0
	OXK		4.0		0

TABLE 4.—ENDEMIC TYPHUS (U.S.A.) AND ROCKY MOUNTAIN SPOTTED FEVER IN RABBITS						
EACH RABBIT RECEIVED 3 RD ENDEMIC TYPHUS VIRUS (TESTICULAR WASHINGS)				EACH RABBIT RECEIVED 1 ST SPOTTED FEVER GUINEA-PIG PASSAGE VIRUS (BLOOD)		
RABBIT NO.	PROTEUS X STRAIN	W-E REACTION BEFORE INJECTION	TEMPERATURE RECORD FOLLOWING INJECTION	W-E REACTION 14 TO 16 DAYS AFTER INJECTION	TEMPERATURE RECORD FOLLOWING INJECTION	W-E REACTION 14 TO 16 DAYS AFTER INJECTION
5232	OX19	20		32.0		4.0
	OX2	40		4.0		4.0
	HX2	20		4.0		4.0
	OXK	20		4.0		4.0
5234	OX19	0		32.0		0.0
	OX2	40		4.0		0.0
	HX2	40		4.0		4.0
	OXK	40		4.0		4.0
5235	OX19	0		10.0		0.0
	OX2	0		0		4.0
	HX2	20		0		4.0
	OXK	20		2.0		0
5237	OX19	0		32.0		0.0
	OX2	40		4.0		4.0
	HX2	20		4.0		4.0
	OXK	20		2.0		4.0
5238	OX19			CONTROLS RABBITS RE- CEIVED ONLY		0
	OX2					32.0
	HX2					1.00
	OXK					0.0
5239	OX19			SPOTTED FEVER VIRUS		4.0
	OX2					32.0
	HX2					1.00
	OXK					4.0

is generally negative. This is in spite of definite infection in most rabbits, as shown by the fact that 20 of 24 boutonneuse fever injected rabbits were subsequently immune to spotted fever. This lack of agglutinin production in rabbits confirms the earlier observation of

Davis and Parker (1934), who have shown that spotted fever vaccine which affords equal protection against the highly virulent viruses of spotted fever and Sao Paulo typhus confers little or no protection against the relatively benign boutonneuse fever, although there is complete cross-immunity between spotted fever and boutonneuse fever in guinea pigs.

TABLE 5.—BOUTONNEUSE FEVER AND ROCKY MOUNTAIN SPOTTED FEVER IN RABBITS


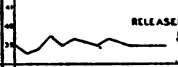
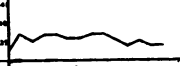
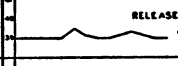
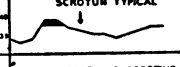


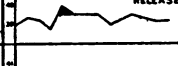


TABLE 5—BOUTONNEUSE FEVER AND ROCKY MOUNTAIN SPOTTED FEVER IN RABBITS									
EACH RABBIT RECEIVED 3 rd BOUTONNEUSE FEVER GUINEA-PIG PASSAGE VIRUS (TESTICULAR WASHINGS)					EACH RABBIT RECEIVED 1 st SPOTTED FEVER GUINEA-PIG PASSAGE VIRUS (BLOOD)				
RABBIT NO.	PROTEUS X STRAINS	W-E REACTION BEFORE INJECTION	TEMPERATURE RECORD FOLLOWING INJECTION C 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16	W-E REACTION 14 TO 16 DAYS AFTER INJECTION	TEMPERATURE RECORD FOLLOWING INJECTION C 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16	W-E REACTION 14 TO 16 DAYS AFTER INJECTION			
5269	OX19	0		0		20	RELEASED ↓	20	
	OX2	0		0		20			
	HX2	0		0		20			
	OXK	0		40		80			
5271	OX19	20		20		20	RELEASED ↓	0	
	OX2	0		0		0			
	HX2	0		0		0			
	OXK	0		0		0			
5273	OX19	0		20		20	RELEASED ↓	80	
	OX2	0		80		80			
	HX2	0		80		80			
	OXK	0		20		40			
5274	OX19	0		0		0	RELEASED ↓	0	
	OX2	0		0		0			
	HX2	0		0		0			
	OXK	0		0		20			
5282	OX19	0		CONTROL RABBIT RECEIVED ONLY SPOTTED FEVER VIRUS			RELEASED ↓	640	
	OX2	0							
	HX2	0							
	OXK	20							

TABLE 6.—HUMAN SERA AS CONTROLS ON THE AGGLUTININABILITY OF PROTEUS X STRAINS

CONTROL SERA		SOURCE	AGG'N (TYPE) TITER AT SOURCE	AGG'N TITER HAMILTON, MONT.		
DISEASE	SEROLOGICAL TYPE			OX19	OX2	OXK
ENDMIC TYPHUS U.S.A.	X19	DR. M'ALPINE MONTGOMERY, ALA.	1- 640 2- 640 3- 640	1280 640 640	0 0 0	0 0 0
TROPICAL TYPHUS MALAYA	X19	DR. LEWTHWAITE KUALA LUMPUR, MALAYA	1925	2560	0	0
TROPICAL TYPHUS MALAYA	XX	DR. LEWTHWAITE KUALA LUMPUR, MALAYA		0	0	2560
SPOTTED FEVER	OX2 (?)	WESTERN UNITED STATES		640	2560	0
SPOTTED FEVER	OX2 (?)	WESTERN UNITED STATES		320	1280	0

In contradistinction to the definite febrile reactions induced in rabbits by the virus of spotted fever or Sao Paulo typhus, the injection of *passage* virus of either boutonneuse fever or endemic typhus seldom induces a rise in temperature. However, X19 agglutinins,

which are absent following the injection of boutonneuse fever virus, may be produced in high titer following the injection of the virus of endemic typhus.

Although it is generally accepted that there is no cross-immunity between spotted fever and endemic typhus in guinea pigs, certain evidence on hand indicates that some degree of added resistance to infection by either virus is conferred by a previous infection with the other. When rabbits are injected first with the virus of endemic typhus and subsequently with spotted fever virus there is little or no serological or other reaction following the latter injection, although control animals show a rise in temperature, scrotal lesions, and a positive Weil-Felix reaction with OX2, OX19, or both. On the other hand rabbits which have shown typical thermal and Weil-Felix reactions following the injection of spotted fever virus may also show a marked rise in agglutinins for OX19 following a subsequent injection of endemic typhus virus. Although this suggests a partial one-way immunity, the failure to obtain reciprocal cross-immunity as indicated by the restimulation of agglutinins in the case just cited may be considered as an expression of the nonidentity of the viruses. Since OX2, as well as OX19, agglutinins are present in both human or rabbit spotted fever sera, and OX2 agglutinins are absent from both endemic typhus human and rabbit sera, it is suggested that the Weil-Felix reaction may be of value in the differential diagnosis, especially in regions where both diseases are present.

The criteria for the differentiation of the main and group agglutinins, as presented by Felix when applied to either spotted fever or Sao Paulo typhus, do not place OX2 agglutinins in the group class. However, my results with human and rabbit sera indicate that both OX19 and OX2 agglutinins may be of the group type, as suggested by Felix and Rhodes (1931) for boutonneuse fever, or that both are of equal main type value.

That differences in agglutinin response to these viruses are, in some instances, due to the ability on the part of certain individuals to react to the infection with the production of only certain types of agglutinins is suggested by human and rabbit spotted fever sera in which only OX2 or only OX19 agglutinins are demonstrable, while in other cases both are present. However, it has been shown by Davis and Parker (1932) that certain spotted fever sera which contain agglutinins in high titer for OX2 and in relatively low titer for OX19, have little or no protective value against the stock strains of *passage* virus. It thus appears that there may be distinct serological varieties of clinical spotted fever and that the type of Weil-Felix reaction may correspond to the protective properties of the respective sera. Further studies bearing on this hypothesis are being made.

The significant suggestion that the type of agglutinins produced is an expression of the antigenic structure of the virus is well supported by such evidence as the agglutination of *Proteus* XK in rural typhus of Malaya and in tsutsugamushi, while in the urban typhus of Malaya and in endemic typhus of the United States agglutinins only of the X19 type are found. These constant serological relationships which exist between the several known types of *Proteus* X and the several varieties of typhus (relationships which confirm, or are confirmed by, generally accepted immunological procedures) have suggested to numerous workers a specific relationship between *Proteus* X organisms and the typhuslike viruses. Regarding this question, it is to be hoped that the continuation of culture studies, such as those of Kuczynski, Fegin, and Anigstein and Amzel and further research on specific soluble substances such as have been made by White, Castaneda and Zia, Castaneda, Kemp, and others, including ourselves, may result in information of conclusive value. Meantime it may be well to keep in mind available information and further possibilities on microbic dissociation without definite commitment to any theory.

In relation to dissociation, Welch and Poole and Welch, Mickle, and Borman have recently made two very pertinent studies on the pleoantigenicity of *Proteus* X19. These authors have shown that this strain may contain normally nonfunctioning agglutinogens which may be freed by spontaneous dissociation and consequently give false positive reactions in the Weil-Felix test with sera from other than the group of typhuslike diseases and false negative reactions with sera from these diseases. It thus appears that the term *Proteus* applies to the antigenic structure as well as to the morphological or colonial structure, and with much greater significance.

SUMMARY

It is shown that agglutinins of *Proteus* OX2, as well as for OX19, appear in significant titer in the serum of rabbits following injection with the *passage* viruses of Rocky Mountain spotted fever or Sao Paulo typhus. Although these agglutinins are perhaps of the group type, they cannot be so considered according to Felix's criteria. Following similar injections with *passage* virus of boutonneuse fever, Weil-Felix tests with the available *Proteus* X strains are essentially negative.

The Weil-Felix reaction with rabbit sera confirms former findings as to the relationships of spotted fever, Sao Paulo typhus, and boutonneuse fever.

The presence of agglutinins of X2 type in human and rabbit spotted fever sera and their absence in human and rabbit endemic typhus (U. S. A.) sera suggest that the Weil-Felix reaction may aid

in the differential diagnosis, especially in regions where both diseases are endemic.

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DEATHS DURING WEEK ENDED MAR. 2, 1935

[From the Weekly Health Index, issued by the Bureau of the Census, Department of Commerce]

	Week ended Mar. 2, 1935	Correspond- ing week, 1934
Data from 86 large cities of the United States:		
Total deaths.....	9,477	9,180
Deaths per 1,000 population, annual basis.....	13.2	12.8
Deaths under 1 year of age.....	694	657
Deaths under 1 year of age per 1,000 estimated live births.....	64	61
Deaths per 1,000 population, annual basis, first 9 weeks of year.....	13.0	12.7
Data from industrial insurance companies:		
Policies in force.....	67,432,737	67,566,955
Number of death claims.....	15,011	15,836
Death claims per 1,000 policies in force, annual rate.....	11.6	12.2
Death claims per 1,000 policies, first 9 weeks of year, annual rate.....	10.8	10.9

PREVALENCE OF DISEASE

No health department, State or local, can effectively prevent or control disease without knowledge of when, where, and under what conditions cases are occurring

UNITED STATES

CURRENT WEEKLY STATE REPORTS

These reports are preliminary, and the figures are subject to change when later returns are received by the State health officers

Reports for Weeks Ended Mar. 9, 1935, and Mar. 10, 1934

Cases of certain communicable diseases reported by telegraph by State health officers for weeks ended Mar. 9, 1935, and Mar. 10, 1934

Division and State	Diphtheria		Influenza		Measles		Meningococcus meningitis	
	Week ended Mar. 9, 1935	Week ended Mar. 10, 1934	Week ended Mar. 9, 1935	Week ended Mar. 10, 1934	Week ended Mar. 9, 1935	Week ended Mar. 10, 1934	Week ended Mar. 9, 1935	Week ended Mar. 10, 1934
New England States:								
Maine.....	2	-----	214	-----	538	1	0	0
New Hampshire.....	-----	-----	-----	2	16	126	0	0
Vermont.....	-----	-----	-----	-----	4	54	0	0
Massachusetts.....	5	19	-----	-----	471	2,356	2	2
Rhode Island.....	-----	4	-----	-----	112	9	0	0
Connecticut.....	7	2	2	2	997	36	3	1
Middle Atlantic States:								
New York.....	21	53	120	122	2,226	1,330	15	4
New Jersey.....	17	15	14	24	1,058	547	3	0
Pennsylvania.....	60	54	-----	-----	5,103	3,063	4	7
East North Central States:								
Ohio.....	41	17	28	21	810	888	9	0
Indiana.....	18	22	70	64	468	750	3	1
Illinois.....	45	23	71	39	2,709	1,473	19	3
Michigan.....	18	18	13	3	2,340	95	1	3
Wisconsin.....	1	5	98	66	2,290	1,278	0	2
West North Central States:								
Minnesota.....	5	4	-----	2	1,813	315	3	0
Iowa.....	5	1	-----	11	1,163	158	6	1
Missouri.....	28	35	243	188	873	1,354	7	2
North Dakota.....	9	1	27	29	33	129	0	0
South Dakota.....	1	3	5	-----	38	837	0	0
Nebraska.....	6	1	-----	-----	336	50	1	1
Kansas.....	4	11	21	-----	1,255	256	1	0
South Atlantic States:								
Delaware.....	2	-----	2	-----	2	269	0	0
Maryland.....	9	7	72	21	141	670	2	0
District of Columbia.....	13	10	3	1	32	555	11	0
Virginia.....	11	26	-----	-----	1,216	1,334	4	2
West Virginia.....	21	14	234	83	518	48	3	0
North Carolina.....	9	25	67	49	607	2,822	4	1
South Carolina.....	5	7	425	871	62	654	15	0
Georgia.....	15	16	387	-----	-----	1,817	0	2
Florida.....	9	6	39	2	36	279	0	0
East South Central States:								
Kentucky.....	15	27	103	113	1,141	635	4	0
Tennessee.....	13	8	228	132	89	1,180	9	8
Alabama.....	8	23	761	102	433	876	4	2
Mississippi.....	9	3	-----	-----	-----	-----	2	0

See footnotes at end of table.

*Cases of certain communicable diseases reported by telegraph by State health officers
for weeks ended Mar. 9, 1935, and Mar. 10, 1934—Continued*

Division and State	Diphtheria		Influenza		Measles		Meningococcus meningitis	
	Week ended Mar. 9, 1935	Week ended Mar. 10, 1934	Week ended Mar. 9, 1935	Week ended Mar. 10, 1934	Week ended Mar. 9, 1935	Week ended Mar. 10, 1934	Week ended Mar. 9, 1935	Week ended Mar. 10, 1934
West South Central States:								
Arkansas.....	8	7	118	105	41	492	2	0
Louisiana.....	22	35	27	16	175	185	3	0
Oklahoma.....	20	15	505	124	188	490	9	0
Texas.....	72	106	2,589	724	163	1,131	9	3
Mountain States:								
Montana.....	6	8		26	111	57	0	1
Idaho.....		1	4		46	19	0	1
Wyoming.....	4				211	77	1	0
Colorado.....	9	6			708	235	1	0
New Mexico.....	7	9	9	2		58	2	0
Arizona.....	1	1	105	17	26	38	0	0
Utah.....	1	1			23	624	2	0
Pacific States:								
Washington.....	3	2	5	2	207	173	2	0
Oregon.....		3	144	81	95	107	1	0
California.....	42	39	377	27	598	1,491	7	2
Total.....	627	693	7,030	2,971	31,522	31,420	174	49

Division and State	Poliomyelitis		Scarlet fever		Smallpox		Typhoid fever	
	Week ended Mar. 9, 1935	Week ended Mar. 10, 1934	Week ended Mar. 9, 1935	Week ended Mar. 10, 1934	Week ended Mar. 9, 1935	Week ended Mar. 10, 1934	Week ended Mar. 9, 1935	Week ended Mar. 10, 1934
New England States:								
Maine.....	0	0	22	10	0	0	0	1
New Hampshire.....	0	0	2	7	0	0	0	0
Vermont.....	0	0	17	6	0	0	0	0
Massachusetts.....	0	1	208	275	0	0	1	1
Rhode Island.....	0	0	15	23	0	0	0	0
Connecticut.....	0	0	70	71	0	0	0	1
Middle Atlantic States:								
New York.....	3	1	952	874	0	0	4	10
New Jersey.....	0	0	166	216	0	0	0	2
Pennsylvania.....	0	1	165	798	0	0	2	9
East North Central States:								
Ohio.....	1	0	1,083	826	0	1	3	2
Indiana.....	0	0	237	261	1	1	0	2
Illinois.....	2	0	1,046	654	1	3	6	6
Michigan.....	0	0	423	801	0	6	2	3
Wisconsin.....	0	1	508	308	22	10	1	2
West North Central States:								
Minnesota.....	1	0	150	66	7	5	0	0
Iowa.....	1	0	67	85	1	18	1	1
Missouri.....	0	0	66	118	2	0	5	2
North Dakota.....	0	0	211	13	3	0	0	0
South Dakota.....	0	0	11	12	1	10	0	0
Nebraska.....	0	1	37	11	17	0	1	0
Kansas.....	0	0	94	97	32	1	0	1
South Atlantic States:								
Delaware.....	0	0	29	11	0	0	0	0
Maryland.....	0	0	109	95	0	0	2	2
District of Columbia.....	0	0	65	17	0	0	0	0
Virginia.....	0	2	38	33	0	0	2	3
West Virginia.....	0	0	158	77	1	0	2	2
North Carolina.....	0	0	41	37	0	0	1	0
South Carolina.....	0	0	5	6	0	0	3	6
Georgia.....	0	0	11	4	0	0	1	9
Florida.....	0	0	8	2	12	0	0	1
East South Central States:								
Kentucky.....	0	0	54	60	1	0	4	6
Tennessee.....	0	0	30	26	0	9	3	3
Alabama.....	0	0	12	10	0	0	1	0
Mississippi.....	0	0	13	5	1	0	2	3

See footnotes at end of table.

Division and State	Poliomyelitis		Scarlet fever		Smallpox		Typhoid fever	
	Week ended Mar. 9, 1935	Week ended Mar. 10, 1934	Week ended Mar. 9, 1935	Week ended Mar. 10, 1934	Week ended Mar. 9, 1935	Week ended Mar. 10, 1934	Week ended Mar. 9, 1935	Week ended Mar. 10, 1934
West South Central States:								
Arkansas.....	0	0	5	5	2	2	1	4
Louisiana.....	0	0	14	22	2	1	5	17
Oklahoma ⁴	0	0	16	17	2	0	1	7
Texas ¹	1	0	121	120	30	39	14	10
Mountain States:								
Montana.....	0	0	19	17	0	0	1	0
Idaho.....	0	0	2	2	0	16	1	0
Wyoming.....	0	0	49	3	14	0	0	0
Colorado.....	1	0	354	24	1	2	0	0
New Mexico.....	0	1	16	24	0	1	8	0
Arizona.....	0	0	24	13	0	0	0	0
Utah ¹	0	0	102	7	0	4	0	0
Pacific States:								
Washington.....	1	3	72	83	29	10	3	5
Oregon.....	0	0	54	38	0	0	0	2
California.....	13	2	266	247	3	4	4	11
Total.....	24	13	7,747	6,537	185	143	85	134

¹ New York City only.² Week ended earlier than Saturday.³ Typhus fever, week ended Mar. 9, 1935, 12 cases, as follows: North Carolina, 2; Georgia, 2; Tennessee, 1; Alabama, 1; Texas, 6.⁴ Exclusive of Oklahoma City and Tulsa.

SUMMARY OF MONTHLY REPORTS FROM STATES

The following summary of cases reported monthly by States is published weekly and covers only those States from which reports are received during the current week.

State	Menin- gococ- cus menin- gitis	Diph- theria	Influ- enza	Malaria	Measles	Pel- lagra	Polio- mye- litis	Scarlet fever	Small- pox	Ty- phoid fever
<i>January 1935</i>										
California.....	20	283	1,504	3	1,239	7	67	1,339	49	43
Nevada.....		3	39		3		0	9	0	0
<i>February 1935</i>										
Arkansas.....	15	32	656	38	163	7	0	75	5	10
Maine.....		5	20		1,117		1	54	0	7
Massachusetts.....	2	42		1	2,098		2	724	0	1
Missouri.....	41	168	2,498	22	2,619		2	486	8	13
Vermont.....		1			20		0	77	0	1

<i>January 1935</i>		<i>January 1935</i>		<i>February 1935</i>	
California:	Cases	Nevada:	Cases	Lead poisoning:	Cases
Chicken pox.....	2,957	Chicken pox.....	40	Massachusetts.....	1
Dysentery, amoebic.....	8	Mumps.....	1	Mumps:	
Dysentery, bacillary.....	17	Septic sore throat.....	1	Maine.....	54
Epidemic encephalitis.....	4	Whooping cough.....	2	Massachusetts.....	290
Food poisoning.....	18			Missouri.....	287
German measles.....	290	<i>February 1935</i>		Vermont.....	7
Granuloma, coccidioidal.....	1	Chicken pox:		Ophthalmia neonatorum:	
Jaundice, epidemic.....	7	Arkansas.....	113	Massachusetts.....	48
Mumps.....	910	Maine.....	202	Missouri.....	1
Ophthalmia neonator- um.....	2	Massachusetts.....	1,202	Rabies in animals:	
Paratyphoid fever.....	2	Missouri.....	386	Massachusetts.....	27
Rabies in animals.....	97	Vermont.....	149	Missouri.....	4
Septic sore throat.....	10	Dysentery:		Septic sore throat:	
Tetanus.....	9	Missouri.....	7	Massachusetts.....	18
Trachoma.....	16	Epidemic encephalitis:		Missouri.....	79
Trichinosis.....	5	Massachusetts.....	1	Tetanus:	
Undulant fever.....	13	German measles:		Massachusetts.....	1
Whooping cough.....	592	Maine.....	147	Trachoma:	
		Massachusetts.....	1,907	Arkansas.....	1
				Massachusetts.....	3
				Missouri.....	5

February 1935		February 1935		February 1935	
Trichinosis:	Cases	Undulant fever:	Cases	Whooping cough:	Cases
Massachusetts.....	22	Maine.....	1	Arkansas.....	42
Tularaemia:		Massachusetts.....	3	Maine.....	173
Arkansas.....	2	Missouri.....	5	Massachusetts.....	817
Missouri.....	4	Vincent's infection:		Missouri.....	280
Typhus fever:		Maine.....	3	Vermont.....	195
Massachusetts.....	1				

WEEKLY REPORTS FROM CITIES

City reports for week ended Mar. 2, 1935

[This table summarizes the reports received regularly from a selected list of 121 cities for the purpose of showing a cross section of the current urban incidence of the communicable diseases listed in the table. Weekly reports are received from about 700 cities, from which the data are tabulated and filed for reference.]

State and city	Diphtheria cases	Influenza		Measles cases	Pneumonia deaths	Scarlet fever cases	Small-pox cases	Tuberculosis deaths	Typhoid fever cases	Whooping cough cases	Deaths, all causes
		Cases	Deaths								
Maine:											
Portland.....	0		0	0	4	4	0	0	1	1	33
New Hampshire:											
Concord.....	0		0	0	2	0	0	1	0	0	14
Nashua.....	0			0		0	0		0	0	
Vermont:											
Barre.....	0		0	0	0	0	0	0	0	3	4
Burlington.....	0		0	15	0	3	0	0	1	0	9
Massachusetts:											
Boston.....	8		0	13	40	40	0	14	0	29	224
Fall River.....	0		0	155	2	0	0	6	0	6	27
Springfield.....	0		0	138	2	8	0	1	0	11	38
Worcester.....	0		0	10	2	10	0	2	0	11	51
Rhode Island:											
Pawtucket.....	0		0	1	0	1	0	0	0	0	22
Providence.....	3		1	21	7	9	0	3	0	7	98
Connecticut:											
Bridgeport.....	0		0	2	1	20	0	0	0	1	24
Hartford.....	1		0	109	3	10	0	3	0	16	55
New Haven.....	0	2	2	119	4	0	0	1	0	0	46
New York:											
Buffalo.....	0		2	227	25	62	0	12	0	25	169
New York.....	27	20	2	683	173	515	0	86	6	236	1,622
Rochester.....	0		0	272	4	10	0	0	1	13	51
Syracuse.....	0		1	78	5	8	0	0	0	17	42
New Jersey:											
Camden.....	6		0	2	8	6	0	1	0	1	41
Newark.....	0	8	0	115	7	23	0	6	0	62	148
Trenton.....	0	1	0	41	5	13	0	0	0	12	49
Pennsylvania:											
Philadelphia.....	7	7	7	16	54	58	0	29	1	124	586
Pittsburgh.....	2	7	5	621	33	45	0	18	0	29	218
Reading.....	0		0	23	1	8	0	0	0	1	30
Scranton.....	1			385		2	0		0	4	
Ohio:											
Cincinnati.....	5	1	0	1	20	28	0	11	0	0	168
Cleveland.....	10	76	3	210	16	47	0	15	0	38	202
Columbus.....	6	3	3	125	5	34	0	3	0	4	99
Toledo.....	1	3	1	37	6	20	0	2	0	2	58
Indiana:											
Fort Wayne.....	4		1	33	1	6	0	0	0	0	26
Indianapolis.....	11		0	35	19	34	0	4	0	13	
South Bend.....	0		0	14	3	10	0	0	0	0	16
Terre Haute.....	2		0	0	0	0	0	0	0	0	16
Illinois:											
Chicago.....	11	14	5	929	68	569	0	41	1	58	739
Springfield.....	0		0	14	2	11	0	0	0	4	31
Michigan:											
Detroit.....	3	11	8	658	54	166	0	23	0	94	338
Flint.....	1		0	618	6	15	0	2	0	10	40
Grand Rapids.....	0		1	52	5	7	0	0	0	9	45
Wisconsin:											
Kenosha.....	0		0	300	0	14	0	0	0	18	13
Milwaukee.....	0		0	621	6	225	0	4	0	34	129
Racine.....	0		0	23	0	8	1	0	0	4	6
Superior.....	0		0	309	0	0	0	0	0	0	9
Minnesota:											
Duluth.....	1		1	425	4	2	0	1	0	0	32
Minneapolis.....	1		0	1,673	5	60	0	2	0	17	106
St. Paul.....	0		0	6	8	27	0	0	0	5	62

City reports for week ended Mar. 2, 1935—Continued

State and city	Diph- theria cases	Influenza		Meas- les cases	Pneu- monia deaths	Scar- let fever cases	Small- pox cases	Tuber- culosis deaths	Ty- phoid fever cases	Whoop- ing cough cases	Deaths, all causes
		Cases	Deaths								
Iowa:											
Davenport	1			2		0	0		0	0	
Des Moines	1			37		7	0		0	0	41
Sioux City	1		0	14	0	2	0	0	0	2	0
Waterloo	1			7		7	0		0	0	
Missouri:											
Kansas City	2	1	0	165	10	19	0	5	0	2	98
St. Joseph	2		0	9	6	1	0	0	0	0	33
St. Louis	24		0	10	21	22	0	14	0	2	261
North Dakota:											
Fargo	0		0	0	1	17	0	1	0	2	7
Grand Forks	0					0	0		0	0	
South Dakota:											
Aberdeen	0			6		0	0	1	0	0	
Nebraska:											
Omaha	1		1	22	8	7	1	0	0	0	63
Kansas:											
Topeka	0		0	45	4	3	0	0	0	6	17
Wichita	2		0	175	6	4	0	0	0	0	22
Delaware:											
Wilmington	0		0	4	9	17	0	0	0	3	29
Maryland:											
Baltimore	1	20	8	10	35	52	0	10	2	21	245
Cumberland	0		0	16	1	3	0	0	0	0	13
Frederick	1		0	0	0	1	0	0	0	0	2
District of Columbia:											
Washington	19	3	2	13	29	55	0	10	0	5	197
Virginia:											
Lynchburg	3		1	195	1	1	0	1	0	3	17
Norfolk	0	3	0	14	6	4	0	1	0	3	36
Richmond	1		1	124	10	7	0	6	0	0	68
Roanoke	1		1	18	1	3	0	1	0	0	20
West Virginia:											
Charleston	0		0	21	0	1	1	0	0	6	9
Huntington	1			17		5	0		0	0	
Wheeling	0		0	135	3	24	0	0	0	7	22
North Carolina:											
Raleigh											
Wilmington	0		0	1	1	0	0	0	0	3	7
Winston-Salem	0	1	0	6	0	2	0	0	0	32	12
South Carolina:											
Charleston	0	43	0	2	8	0	0	4	0	1	31
Columbia	0		0	0	3	0	0	1	0	0	13
Greenville	0		0	0	3	0	0	0	0	0	7
Georgia:											
Atlanta	2	50	3	2	14	6	0	5	0	2	95
Brunswick	0		0	0	0	0	0	0	0	0	2
Savannah	0	41	1	0	3	0	0	3	0	1	31
Florida:											
Miami	0		0	0	3	1	0	4	0	1	56
Tampa	2		0	4	4	2	0	2	0	0	29
Kentucky:											
Ashland	1	23	0	0	0	0	0	0	0	3	0
Lexington	0		0	20	6	1	0	2	0	0	18
Louisville	2	22	1	313	14	6	0	3	0	14	84
Tennessee:											
Memphis	4		3	2	13	9	0	2	2	4	92
Nashville	0		2	2	18	3	0	4	0	5	65
Alabama:											
Birmingham	2	40	6	34	10	2	0	7	0	6	75
Mobile	1	1	2	2	1	0	0	1	0	0	18
Montgomery	2	34		11		0	0		0	2	
Arkansas:											
Fort Smith											
Little Rock	1		0	23	8	2	0	1	0	0	11
Louisiana:											
New Orleans	16	6	7	1	18	6	0	16	1	0	199
Shreveport	1		0	20	13	0	0	5	0	3	41
Oklahoma:											
Tulsa	0			0		4	0		0	4	
Texas:											
Dallas	6	5	3	0	14	2	0	8	0	0	74
Fort Worth	0		2		15	5	0	0	0	0	52
Galveston	1		0	0	1	1	0	1	0	0	13
Houston	3		1	3	12	0	0	9	0	0	86
San Antonio	0	0	8	2	8	2	0	8	0	0	50

City reports for week ended Mar. 2, 1935—Continued

State and city	Diphtheria cases	Influenza		Measles cases	Pneumonia deaths	Scarlet fever cases	Small-pox cases	Tuberculosis deaths	Typhoid fever cases	Whooping cough cases	Deaths, all causes
		Cases	Deaths								
Montana:											
Billings.....	1		0	5	0	2	0	0	0	0	7
Great Falls.....	1		0	118	0	0	3	0	0	8	5
Helena.....	0		0	71	2	0	0	0	0	2	5
Missoula.....	0		0	0	0	0	0	0	0	5	7
Idaho:											
Boise.....	0		0	1	1	0	0	1	0	0	11
Colorado:											
Denver.....	10	41	0	306	8	187	0	4	0	0	72
Pueblo.....	0		0	109	2	5	0	1	0	1	14
Utah:											
Salt Lake City..	0		3	3	4	62	0	3	0	54	58
Nevada:											
Reno.....	0		0	0	0	1	0	0	0	0	0
Washington:											
Seattle.....	0		2	42	5	8	2	7	0	5	91
Spokane.....	0	1	1	145	0	3	1	1	0	3	36
Tacoma.....	0		0	0	3	3	5	0	0	0	24
Oregon:											
Portland.....	0		0	68	5	11	0	2	0	0	100
Salem.....	0	3		1		0	0		0	0	
California:											
Los Angeles.....	12	71	6	23	27	72	1	25	0	9	367
Sacramento.....	10		0	40	1	6	0	1	0	0	31
San Francisco....	0	7	1	8	8	25	0	8	0	13	190

State and city	Meningococcus meningitis		Polio-myelitis cases	State and city	Meningococcus meningitis		Polio-myelitis cases
	Cases	Deaths			Cases	Deaths	
Massachusetts:				Kansas:			
Boston.....	1	0	0	Wichita.....	1	0	0
Worcester.....	1	1	0	Maryland:			
New York:				Baltimore.....	4	1	1
New York.....	12	2	0	District of Columbia:			
Pennsylvania:				Washington.....	6	2	0
Philadelphia.....	2	0	0	North Carolina:			
Ohio:				Wilmington.....	1	1	0
Cincinnati.....	13	10	0	Kentucky:			
Toledo.....	1	0	0	Ashland.....	1	0	0
Indiana:				Lexington.....	1	1	0
Indianapolis.....	3	1	0	Tennessee:			
Illinois:				Memphis.....	4	0	1
Chicago.....	11	1	0	Nashville.....	2	1	0
Springfield.....	1	0	0	Alabama:			
Michigan:				Birmingham.....	1	1	0
Detroit.....	1	0	0	Montgomery.....	1	0	0
Minnesota:				Oklahoma:			
Minneapolis.....	2	1	0	Tulsa.....	4	0	0
Iowa:				Texas:			
Davenport.....	1	0	0	Dallas.....	4	0	0
Sioux City.....	5	0	0	Fort Worth.....	2	1	0
Missouri:				Houston.....	1	0	0
Kansas City.....	2	0	0	Washington:			
St. Louis.....	4	1	0	Seattle.....	0	0	1
Nebraska:				California:			
Omaha.....	2	4	0	Los Angeles.....	1	1	3

Epidemic encephalitis.—Cases: New York, 1; Newark, 1; Chicago, 1; St. Louis, 1; Miami, 1; ~~Spokane, 1; San Francisco, 1.~~

Pellagra.—Cases: Philadelphia, 1; Norfolk, 1; Winston-Salem, 1; Charleston, S. C., 1; Atlanta, 2; Savannah, 1; Dallas, 1; San Francisco, 1.

Typhus fever.—Savannah, 2 cases.

FOREIGN AND INSULAR

CANADA

Provinces—Communicable diseases—2 weeks ended February 23, 1935.—During the 2 weeks ended February 23, 1935, cases of certain communicable diseases were reported by the Department of Pensions and National Health of Canada, as follows:

Disease	Prince Edward Island	Nova Scotia	New Brunswick	Quebec	Ontario	Manitoba	Saskatchewan	Alberta	British Columbia	Total
Cerebrospinal meningitis.....		1	1	2		3				7
Chicken pox.....		6	4	289	694	58	76	20	102	1,249
Diphtheria.....		3	1	37	14	14	5			74
Dysentery.....				5	4					9
Erysipelas.....		1		10	8	1	1	1	6	23
Influenza.....		76	1	34	430	1			167	709
Measles.....		147	11	930	3,406	651	500	17	97	5,759
Mumps.....		31			666	33		11	49	790
Pneumonia.....		11			65		6		30	112
Scarlet fever.....	1	10	14	283	325	40	33	21	47	774
Smallpox.....					1					1
Trachoma.....						1	2			3
Tuberculosis.....	5	2	8	116	100	16	2	6	35	290
Typhoid fever.....				19	9	2				31
Undulant fever.....				1	4					5
Whooping cough.....	3	8	3	188	367	78	28	3	115	793

JAMAICA

Communicable diseases—4 weeks ended February 23, 1935.—During the 4 weeks ended February 23, 1935, cases of certain communicable diseases were reported in Kingston, Jamaica, and in the island outside of Kingston, as follows:

Disease	Kings- ton	Other locali- ties	Disease	Kings- ton	Other locali- ties
Chicken pox.....	2	11	Puerperal fever.....	1	5
Dysentery.....	6	3	Tuberculosis.....	31	74
Erysipelas.....		2	Typhoid fever.....	8	32
Leprosy.....		3			

CHOLERA, PLAGUE, SMALLPOX, TYPHUS FEVER, AND YELLOW FEVER

(NOTE.—A table giving current information of the world prevalence of quarantinable diseases appeared in the PUBLIC HEALTH REPORTS for Feb. 22, 1935, pp. 267-279. A similar cumulative table will appear in the PUBLIC HEALTH REPORTS to be issued Mar. 29, 1935, and thereafter, at least for the time being, in the issue published on the last Friday of each month.)

Cholera

Ceylon—Colombo.—During the week ended February 23, 1935, 2 cases of cholera were reported at Colombo, Ceylon.

Persia—Bushire.—During the week ended March 2, 1935, 4 cases of cholera with 3 deaths were reported at Bushire, Persia.

Siam—Nagara Rajsima—Roy Ech.—During the week ended March 2, 1935, 13 cases of cholera with 2 deaths were reported at Roy Ech, Nagara Rajsima, Siam.

Plague

Canary Islands—Las Palmas.—During the week ended January 19, 1935, 1 case of plague was reported at Las Palmas, Canary Islands.

China—Amoy.—On February 24, 1935, 1 imported fatal case of plague was reported at Amoy, China.

Dutch East Indies—Cheribon.—During the week ended February 23, 1935, 1 imported fatal case of plague was reported at Cheribon, Dutch East Indies.

Egypt—Asyut.—During the week ended March 2, 1935, 1 case of plague with 1 death was reported at Asyut, Egypt.

Siam—Rajpuri.—During the week ended March 2, 1935, 1 case of plague was reported at Rajpuri, Siam.

Smallpox

Ceylon—Welitara.—A report dated March 7, 1935, states that from January 31, 1935, 20 cases of smallpox had been reported at Welitara, Ceylon.

Typhus Fever

China—Tientsin.—During the week ended January 19, 1935, 1 case of typhus fever was reported at Tientsin, China.

Colombia.—During the week ended January 19, 1935, 1 death from typhus fever was reported at Colombia.

Yellow Fever

Colombia—Intendencia of Meta—Restrepo.—During the week ended January 26, 1935, 3 deaths from yellow fever were reported at Restrepo, Intendencia of Meta, Colombia.